

# **SOCKET-WELDED PIPE JOINT AND FITTING AND ASSEMBLY FOR MAKING SAME**

## **RELATED APPLICATIONS**

[0001] This application discloses and claims subject matter which was disclosed in provisional patent application Serial No. 60/418,061 filed October 11, 2002 and provisional patent application Serial No. 60/449,471 filed February 24, 2003, both of which provisional applications are titled "Socket Welded Joint".

## **TECHNICAL FIELD**

[0002] This invention pertains to the field of welding metal pipe segments and metal pipe fittings to each other and to equipment.

## **BACKGROUND**

[0003] In plants such as power plants, process plants, and the like, it is necessary to transfer fluids, including liquids, gases, and fluidized solids, from one location to another, and between different equipment. This is accomplished by piping layouts. When a piping layout is created, it must provide for changing directions of the piping, connecting two or more pipe segments, and/or connecting pipe segments to equipment components or fittings.

[0004] Based on issued patents relating to welding and pipe connections, as well as on a survey of the industry, it can be said that there are presently two approaches for making such welded connections. One is known as a butt-welded connection, in which both the connecting elements are butted against each other and welded together. The other is known as a socket-welded connection, in which one of elements is a socket and the other is a pipe segment. An end of the pipe segment is inserted into the socket, and the two are welded together. Socket-welded connections are commonly used in small

diameter piping. In nuclear power plants, for example, socket-welded connections are normally used only in piping with a nominal diameter of two inches and smaller. Normally, butt-welded joints are stronger than socket-welded joints. However, the construction tolerances for butt-welded joints are more stringent than those for socket-welded joints.

[0005] In many butt-welded joints, the end surfaces of the pipes being joined are beveled or chamfered. As disclosed in U.S. patents No. 1,842,298 and No. 1,903,315, some socket-welded joints may simulate a butt-welded joint, as far as the shape of the weld is concerned. Such simulations required a non-standard pipe having on its outer surface a dam for confining the added weld metal, which dam must be configured and positioned to specifically complement a particular fitting.

[0006] Failures of socket-welded connections have been identified in the past, resulting in a loss of production and revenues due to shutdown of plants. These pipe segments may contain high-pressure fluid. Bursting of such a pipe segment can result in personal injury, even death. Significant research has been performed to reduce these failures. The following are examples of such research papers:

- ◆ J. K. Smith, "Vibrational Fatigue Failures in Short Cantilevered Piping with Socket-Welded Fittings," ASME PVP-Vol.338-1, 1996.
- ◆ P. C. Riccardella et al, "Fracture Mechanics Analysis of Socket-Welds under High Cycle Vibrational Loading," ASME PVP-Vol.353, 1997.
- ◆ M. Higuchi et al, "Fatigue Strength of Socket-Welded Pipe Joints," ASME PVP-Vol. 313-1, 1995.
- ◆ M. Higuchi et al, "A Study on Fatigue Strength Reduction Factor for Small Diameter Socket-Welded Pipe Joints," ASME PVP-Vol. 338-1, 1996.

[0007] It is well known in the industry that the process of welding creates significant residual stresses in the components welded together. These stresses are so strong that they are capable of warping very thick steel plates. Research directed to failures of socket-welded fittings attributes the failures to such residual stresses created

by the welding process. To reduce the residual stresses created by the welding process, the welding process needs to be very, very slow. The research has also led to recommendations that welding beads be applied in a very specific sequence. These recommendations are difficult to follow in practice, and they tend to be costly and time-consuming.

## **SUMMARY OF THE INVENTION**

[0008] The object of this invention is to provide a socket-welded pipe joint which is practical, provides better fusion of metal, and reduces residual stresses. These will result in fewer failures of the joints. In the first two embodiments, the end of fitting is configured so that the fusion of the base metal of the end portion of the fitting will help to reduce the residual stresses at the root of the joint. These are the simpler of the embodiments presented herein. The remaining four embodiments will help to reduce the residual stresses at both the toe and the root of the joint by using the heat in better fusion of the base metal. Six embodiments of the invention achieve these objectives.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

[0009] Fig. 1 is a perspective view of an end of a prior art socket-welded fitting.

[0010] Fig. 2 is a fragmentary section view showing a socket-welded joint including the fitting shown in Fig. 1.

[0011] Fig. 3 is a detailed view of a portion of the joint shown in Fig. 2.

[0012] Fig. 4 is a perspective view showing a socket-welded fitting of the first embodiment of the invention.

**[0013]** Fig. 5 is a fragmentary section view showing a socket-welded joint including the fitting shown in Fig. 4.

**[0014]** Fig. 6 is a detailed view of a portion of the joint shown in Fig. 5.

**[0015]** Fig. 7 is a perspective view showing a socket-welded fitting of the second embodiment of the invention.

**[0016]** Fig. 8 is a fragmentary section view showing the assembled components of a socket-welded joint including the fitting shown in Fig. 7, before welding.

**[0017]** Fig. 9 is a fragmentary section view showing a socket-welded joint including the fitting shown in Fig. 7, after welding.

**[0018]** Fig. 10 is a detailed view of a portion of the joint shown in Fig. 8.

**[0019]** Fig. 11 is a detailed view of a portion of a joint, similar to the one shown in Fig. 8, with a curved edge.

**[0020]** Fig. 12 is a perspective view showing a socket-welded fitting of the third embodiment of the invention.

**[0021]** Fig. 13 is a fragmentary section view showing the assembled components of a socket-welded joint including the fitting shown in Fig. 12, before welding.

**[0022]** Fig. 14 is a fragmentary section view showing a socket-welded joint including the fitting shown in Fig. 12, after welding.

**[0023]** Fig. 15 is a detailed view of a portion of the joint shown in Fig. 13.

**[0024]** Fig. 16 is a perspective view showing a socket-welded fitting of the fourth embodiment of the invention.

**[0025]** Fig. 17 is a fragmentary section view showing the assembled components of a socket-welded joint including the fitting shown in Fig. 16, before welding.

**[0026]** Fig. 18 is a fragmentary section view showing a socket-welded joint including the fitting shown in Fig. 16, after welding.

**[0027]** Fig. 19 is a detailed view of a portion of the joint shown in Fig. 17.

**[0028]** Fig. 20 is a perspective view showing a socket-welded fitting of the fifth embodiment of the invention.

**[0029]** Fig. 21 is a fragmentary section view showing the assembled components of a socket-welded joint including the fitting shown in Fig. 20, before welding.

**[0030]** Fig. 22 is a fragmentary section view showing the assembled components of a socket-welded joint including the fitting shown in Fig. 20, after welding.

**[0031]** Fig. 23 is a detailed view of a portion of the joint shown in Fig. 21.

**[0032]** Fig. 24 is a detailed view of a portion of the joint, similar to the one shown in Fig. 21, with curved edges.

**[0033]** Fig. 25 is a detailed view of a portion of the joint for the sixth embodiment, similar to the one shown in Fig. 21, without bars.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0034] Figures 1 and 2 illustrate a typical socket-welded connection presently used in the industry. The socket-welded fitting shown in Figure 1 is available in the market. If the pipe segment is to be connected to equipment, the equipment may be configured like an end of a socket-welded fitting. Figure 2 shows an end of pipe segment 2 inserted in the end of a socket-welded fitting 1. They are joined together by a weld 3. The view in Figure 2 is after the welding is performed with some of the pipe and fitting base metal fused. It will be understood that the fused metal shown in this figure and other figures are for illustration purposes, as the precise locations of the boundaries between fused and unfused metal cannot be accurately predicted due to many variables that control the melting of the metal. The gap in the axial direction between pipe segment 2 and the edge inside the socket-welded fitting is a standard practice and it is believed that it reduces residual stresses. The gap between socket-welded fitting 1 and piping segment 2 in the radial direction is a standard practice, makes the construction easier, and is due to the difference between the inner diameter of the socket-welded fitting 1 and the outer diameter of the pipe segment 2. As shown in Figures 1-3 and other figures of the drawings, these gaps are exaggerated for purposes of illustration. Failures of this type of joint may initiate at a "toe" or "root" of the weld. Location 9 in Figure 3 is called a "toe" and location 10 a "root". The present invention is believed to be an improvement upon the prior art shown in Figs. 1-3.

[0035] The first embodiment of the invention is shown in figures 4, 5 and 6. Similar to the prior art configuration, this embodiment has modified socket-welded fitting 101, the end of the pipe segment 102 inserted inside the socket, and a weld 103. The view in Figure 5 is after the welding is performed with some of the pipe and fitting base metal fused. The difference between the prior art configuration shown in Figures 1-3, and this embodiment is that the edge 104 is chamfered as shown in Figure 5, while prior art edge 4 shown in Figure 2 is vertical and 90° to the wall of the pipe segment 2. (As used herein, the term "chamfer" refers to an annular surface which has been cut, or is shaped as though it had been cut, from surface which included a 90 degree angle; as viewed in cross

section, the surface of the chamfer may include one or more straight lines and/or curves.) Additionally, the size and profile of the weld 103 in Figure 5 may be different compared to the profile of the weld 3 in Figure 2. The weld size and profile have to be determined in all the embodiments based on the diameter and the thickness of pipe segment and the necessary strength of the weld joint. The slanting edge, in which the entire chamfer is a straight line, is shown for the whole thickness of the fitting in figures 5 and 6. However, the slanting edge can terminate at a smaller height. This is applicable to all the embodiments identified here. The example of this type of edge is illustrated in Figure 25.

[0036] Figure 6 shows the angle 108 between the edge 104 and the longitudinal axes of the fitting and the pipe. For the best joint, angle 108 should be between 60° and 80° so that the supplemental angle is between 100° and 120°.

[0037] The advantage of the first embodiment is that some of the heat of the welding will be used in melting the base metal at the bottom apex of the edge 104, thereby reducing the residual stresses and providing better fusion. This is the simplest embodiment.

[0038] The second embodiment is shown in figures 7, 8, 9 and 10. Similar to the first embodiment, the second embodiment has modified socket-welded fitting 201, the end of the pipe segment 202 inserted inside the socket, and a weld 203. In addition, chamfered edge 204 includes the surface of lip 205, which is similar to lips in butt-welded joints. The weld size and profile in this embodiment will also have to be determined based on the diameter and the thickness of the pipe segment and the necessary strength of the weld joint. The detail of the end of the modified socket-welded fitting is shown in Figure 10. Lip length 211 and lip thickness 212 are to be determined based on the diameter and the thickness of the pipe end and the necessary strength of the weld joint. For the best joint, the lip angle 213 should be between 0° and 30°. The view in Figure 8 is before the welding is performed. The view in Figure 9 is after the welding is performed with some of the pipe and fitting base metal fused.

[0039] The advantages of this embodiment are that more of the heat of the welding will be used in melting the base metal of the lip 205 and some of the base metal at the bottom apex of the edge 204 reduces the residual stresses and provides better fusion. However, this embodiment is slightly more complicated than the first embodiment.

[0040] Figure 11 shows a variation of the second embodiment in which the surface of lip 205A merges gradually into the remainder of chamfered edge 204A. That is, the profile of the major portion of the chamfered edge is a curve rather than two intersecting straight lines.

[0041] The third embodiment is shown in the Figures 12, 13, 14 and 15. Similar to the second embodiment, this embodiment has modified socket-welded fitting 301, the end of the pipe segment 302 inserted inside the socket, and a weld 303. Chamfered edge 304 includes inwardly flared surface 305 and thin metal bars 306 extending parallel to the longitudinal axis. The size and number of the bars will be based on the diameter and the thickness of the pipe segment 302 and the necessary strength of the weld joint. Chamfered edge 304 also includes a ring 307, which provides better fusion and reduces residual stresses at the toe of the weld. The metal bars 306 are provided to connect the ring 307 to, and accurately spaces it from, the rest of the fitting. The size of the ring 307 will be based on the diameter and the thickness of the pipe segment 302 and the necessary strength of the weld joint. The detail of the end of the modified socket-welded fitting for the third embodiment is shown in Figure 15. The dimensions 311, 312, 321 and 323 are to be determined based on the thickness of the pipe end and the necessary strength of the weld joint. The angle 313 should be between 0° and 30°. The angle 313 may be continued for metal bars 306 or a different angle may be used. The angle 313 may be continued for ring 307 or different angle may be used. The view in Figure 13 is before the welding is performed. The view in Figure 14 is after the welding is performed and shows some of the pipe and fitting base metal fused. The cross sections shown in the figures 13 and 14, and the corresponding drawings for the fourth and fifth embodiments,



are through the bars. However, as is best shown by Figure 12, most of the welding will be between the bars 306.

[0042] The advantage of this third embodiment is that more heat of the welding will be used in melting the base metal of the flared surface 305, metal bars 306, and the metal ring 307, as well as some of the base metal of the remaining, larger diameter portion of edge 304, thereby reducing the residual stresses and providing better fusion. This embodiment will also provide reduction in the failure initiated at the toe of the weld 303 in addition to reducing failure at the root. However, this embodiment is slightly more complicated than the first two embodiments.

[0043] The fourth embodiment is shown in Figures 16, 17, 18 and 19. Similar to the third embodiment, this embodiment has modified socket-welded fitting 401, the end of the pipe segment 402 inserted inside the socket, and a weld 403. Chamfered edge 404 includes inwardly flared surface 405 and thin metal bars 406 extending parallel to the longitudinal axis. The size and number of the bars will be based on the diameter and the thickness of the pipe segment 402 and the necessary strength of the weld joint. Chamfered edge 404 also includes outwardly flared surface 415 at the end of the metal bars 406, providing better fusion, and reducing residual stresses at the toe of the weld. A thicker ring 417 is provided at the terminus of chamfered edge 404. The detail of the end of the modified socket-welded fitting for the fourth embodiment is shown in Figure 19. The dimensions 411, 412, 414, 420, 421 and 424 are to be determined based on the thickness of the pipe end and the necessary strength of the weld joint. The angle 413 should be between 0° and 30°. The angle 413 may be continued for metal bar 406 or a different angle may be used. The angle of the flared surface 415 is identified as 416, and thickness of ring 417 is identified as 414. The angle 416 should be between 0° and 30°. As mentioned previously, the weld size and profile will have to be determined based on the diameter and the thickness of the pipe segment and the necessary strength of the weld joint. The weld directly deposited on the pipe induces residual stresses. Additional welding metal deposit on the weld or fitting in the vicinity of the pipe will reduce the induced residual stresses. Hence, the welding should not go beyond the edge of the

socket-welded fitting in order to minimize the residual stresses in the pipe adjacent to the weld. This can also be done in the third, fifth, and sixth embodiments. The view in Figure 17 is before the welding is performed. The view in Figure 18 is after the welding is performed and shows some of the pipe and fitting base metal fused.

[0044] The advantage of this fourth embodiment is that more heat of the welding will be used in melting the base metal having the inwardly flared surface 405, metal bars 406 and metal ring 417, as well as some of the base metal of the remaining, larger diameter portion of edge 404, thereby reducing the residual stresses and providing better fusion. Fusion of the base metal at the flared surface 415 and the additional thickness of the ring 417 will reduce the residual stresses in the pipe adjacent to the weld, reducing the possibility of a failure initiated at the toe of weld 403. However, this embodiment is more complicated compared to the first three embodiments.

[0045] The fifth embodiment is shown in Figures 20, 21, 22 and 23. Similar to the fourth embodiment, this embodiment has modified socket-welded fitting 501, the end of the pipe segment 502 inserted inside the socket, and a weld 503. Chamfered edge 504 includes inwardly flared surface 505 and thin metal bars 506 extending parallel to the longitudinal axis. The size and number of the bars will be based on the diameter and the thickness of the pipe segment 502 and the necessary strength of the weld joint. Chamfered edge 504 also includes outwardly flared surface 515 at the end of the metal bars 506 for stability, providing better fusion, and reducing residual stresses at the toe of weld 503. The detail of the end of the modified socket-welded fitting for the fifth embodiment is shown in Figure 23. The dimensions 511 and 512 are to be determined based on the thickness of the pipe end. The angle 513 should be between 0° and 30°. The angle 513 may be continued for metal bar 506 or different angle may be used. In addition to outwardly flared surface of 515, which corresponds to outwardly flared surface of 415 in the fourth embodiment, another outwardly flared surface 518 and thicker ring 517 are included in this embodiment. The angle of the flared surface 515 is identified as 516, and the length of flared surface 515 as 521. The angle 516 should be between 0° and 30°. The angle 519 for the flared surface 518 should be between 60° and 80°. The length of flared

surface 518 is identified as 522. The thickness of the ring 517 is identified as 514. This edge shape creates an annular well for deposit of the weld material, will increase the strength of the joint and minimize chances of weld material going beyond the edge of the fitting. This edge shape will also minimize the residual stresses in the pipe adjacent to the weld. The view in Figure 21 is before the welding is performed. The view in Figure 22 is after the welding is performed and shows some of the pipe and fitting base metal fused.

[0046] The advantage of this fifth embodiment is that more heat of the welding will be used in melting the base metal of the lip 505, metal bars 506, and metal ring 517, as well as some of the base metal of the remaining, larger diameter portion of edge 504, thereby reducing the residual stresses and providing better fusion. Fusion of the base metal at the outwardly flared surfaces 515 and 518 and the additional thickness of the ring 517 will reduce the residual stresses in the pipe adjacent to the weld, thereby reducing the possibility of a failure initiated at the toe 9 (as identified in Figure 3) in addition to reducing possibility of a failure initiated at the root 10 (as identified in Figure 3). However, this embodiment is the most complicated of the embodiments proposed here.

[0047] The advantages of the bars in the third, fourth and fifth embodiments are that the bar allows a fixed distance between the main fitting and the ring and connect them together for ease of handling and manufacturing efficiency.

[0048] The sixth embodiment is shown in Figure 25. If flexibility in width of the weld is needed, the bars used in the third, fourth and fifth embodiments can be eliminated. The fitting will be made into two pieces. The distance between the two pieces can be increased or decreased according to the size of the weld required. The residual stresses will be reduced at both the toe and the root locations due to melting of the end portions of the fitting 601 and the ring 607. The chamfered edges 604 and 608 are similar to the chamfered edges described previously.

**[0049]** Instead of a circular cross section, the fitting, pipe and weld may have an elliptical or other non-circular cross section.

**[0050]** It will be understood that, while presently preferred embodiments of the invention have been illustrated and described, the invention is not limited thereto, but may be otherwise variously embodied within the scope of the following claims.